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Southern Region

Increase Tree Growth & Income from Forest Fertilization.

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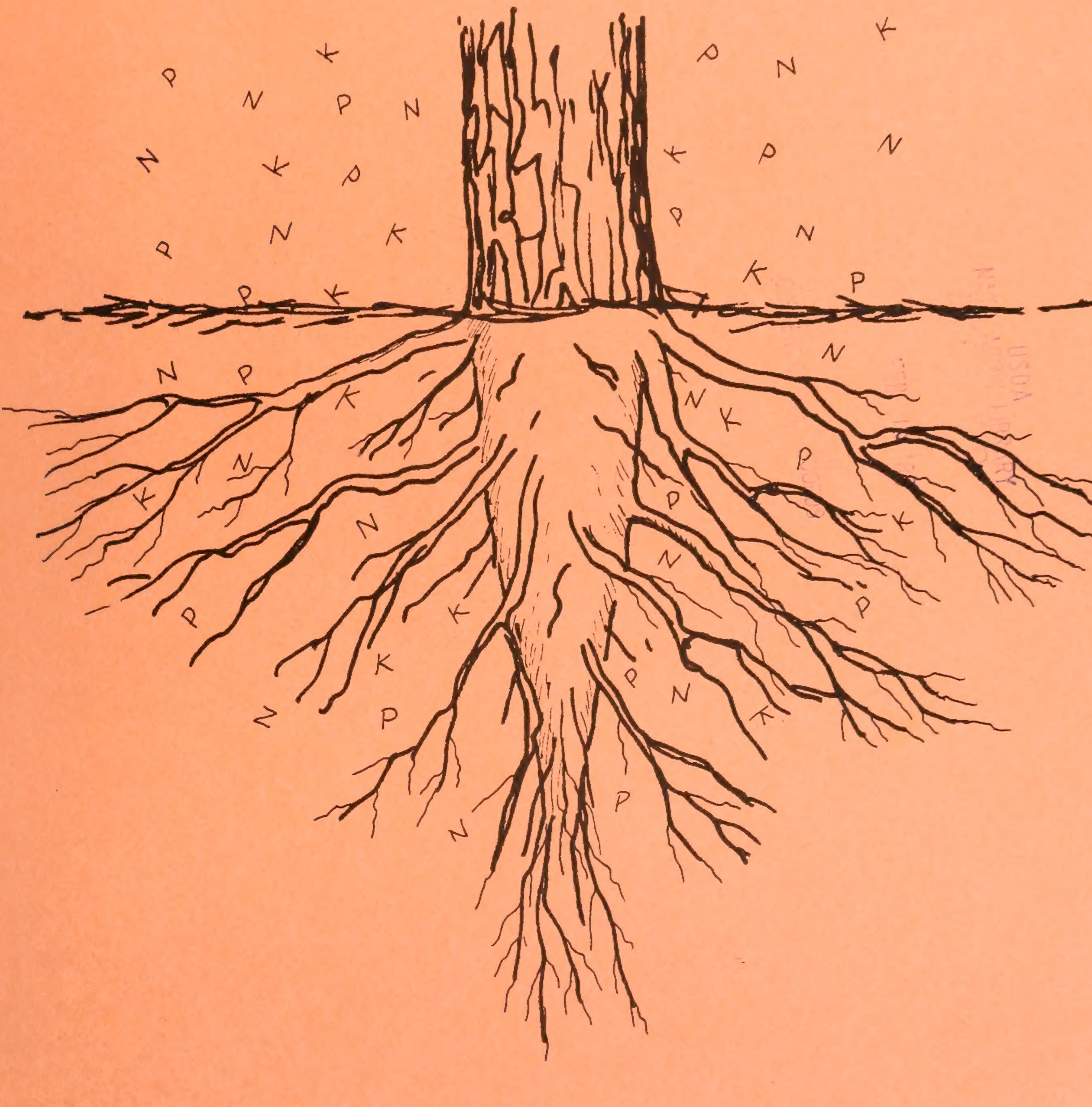

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JUNE 1984

INCREASE GROWTH AND INCOME FROM FOREST FERTILIZATION

by

John R. Vann [1]

Introduction

Forestry, in the early 1900's, was perhaps the most prosperous form of agriculture in the United States. The nation's timber was being harvested at an alarming rate, and unsatisfactory techniques in harvesting, and the lack of proper site preparation and reforestation were depleting the nation's forests and robbing forest lands of their inherent fertility. Strong winds and heavy rainstorms were accelerating erosion on the exposed, deforested lands. Very little capital was available from banks or other sources to stimulate improved technology for investments on forest lands until after the midpoint of the century. In the late 1960's interest in maintaining and improving forest productivity became economically practical, when researchers proved that the quality of some sites could be improved substantially if chemical fertilizers were used with specific management practices (figure 1).

Before 1960, timber on poorly drained sandy soils of the Atlantic and Gulf Coastal Plains was not managed for forestry by landowners. Instead, these stands were either liquidated or left idle for years stocked with low quality timber. The owners did not know the real potential of these areas to produce good quality sawtimber and pulpwood. These same areas today offer a golden opportunity for private non-industrial landowners and large commercial enterprises to increase their profits from timber through forest fertilization. As in agriculture, application of fertilizers to forest stands must be preceded by decisions on where to apply it, on what sites or stand conditions to apply it, what fertilizer element to use, the timing and rate of fertilizer application, and method of application. This bulletin presents data showing how well certain soils respond to phosphorus (P) fertilization in conjunction with other silvicultural practices on the Atlantic and Eastern Gulf Coastal Plain.

Generally southern pines response to P fertilization is greater and more consistent than to other nutrients used in the South. Thus, P is the primary nutrient of concern in the coastal areas of the southeast. Therefore, strong emphasis is placed on this fertilizer element.

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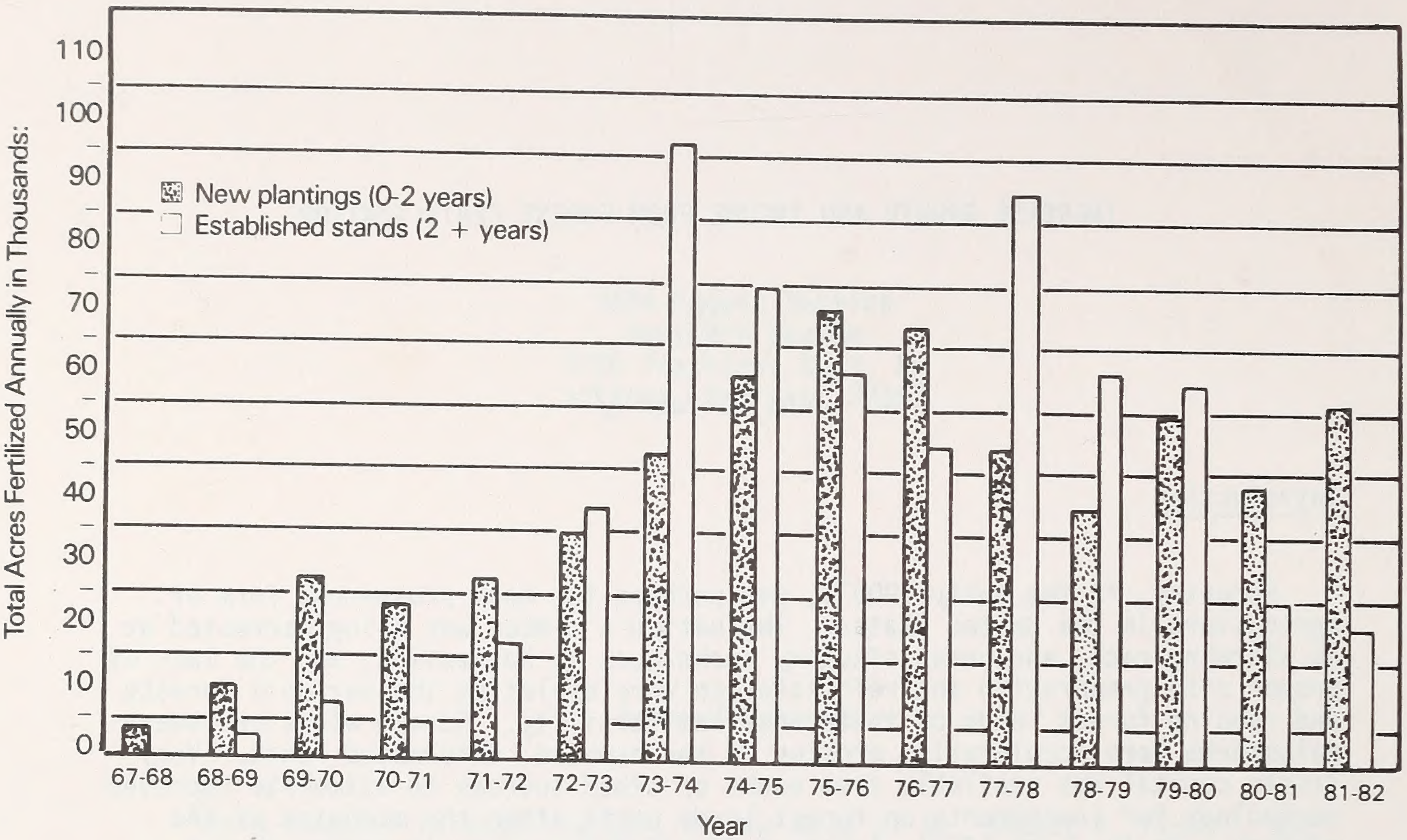

Figure 1.—Acres of pineland fertilized annually in the U.S. Southeast: established stands, and new planting through 1977-78. Data for 1967-1978 derived from figure 2, G. W. Bengston, Forest Fertilization in the United States: J. For. 78(4): April 1979. Data for 1979-1983 derived from figure 1, H. Lee Allen, Forest Fertilization, In NCSFFC Forest Soils Shortcourse, July 1, 1983, Raleigh, NC: North Carolina State University. 1983; p. 129-159.)

Selection of Responsive Sites

Guidelines have been developed for the identification of P-responsive sites based on the CRIFF soil groupings for the Southeastern Coastal Plain. The same criteria for grouping soils in Florida coastal plains can be used in identifying responsive soils in the adjoining coastal areas of Georgia, South Carolina, North Carolina and Virginia. The CRIFF scheme places soils into eight broad groupings with similar physical and chemical properties using the USDA Soil Conservation Service's is Soil Taxonomic Classification System (table 1, columns 1-4).

The purpose of the CRIFF soil scheme is to estimate the responsiveness of soil properties to fertilization. More recently, managers of forest lands have recognized the grouping of soil properties as a valuable tool in making silvicultural decisions. Most soil data necessary to categorize a site into the CRIFF scheme can be easily obtained in the field or from existing soil surveys. According to the CRIFF groupings, soils that are fine-textured (heavy loams or clays), wet, and contain less than 5 ppm of available P have a greater and more consistent response to addition of P than soils that are coarse-textured (sandy), and wet, with similar amounts of available P. Soils that are dry, moderately deep to deep (36 + inches), with either textural class (clays or sandy loams) usually have the least response when P is added, and deep dry sands usually, will not respond to P at all.

Table 1. — SOIL INTERPRETATIONS FOR FOREST FERTILIZATION WITH PHOSPHOROUS IN THE SOUTHEASTERN COASTAL PLAIN[1]

1	2	3		4		5				6	7	8	9		10		11		12		13	14	15	16
CRIFF Soil Group	Soils of the Atlantic Coastal Plain of FL, GA, SC, and NC with drainage characteristics	Spodic horizon[3]		Clay layer		Species in order of preference				Site prep. and reg. methods in order of preference	Access drainage[4]	Artificial silvicultural drainage[5]	Soil test (slash) 5ppm P[6]		Soil test (lob) 3ppm P		Foliar test (slash) .09% P		Foliar test (lob) .10% P		Fert. source lbs/acre at planting[7]	Fert. source lbs/acre mid-rotation or after thinning[7]	Probability of response[8,9] %	Volume gained cu. ft./ac./yr. (estimated)[8,9]
		present	Absent	20" or less	20" or more	lob	SL	LL	Hwd.				<	>	<	>	<	>	<	>				
A	Savanna soils, fine-textured, heavy loams, VP-SWP drainage[2]		X	X		1	2	—	3	Chop, burn, chop, double bed, plant; or chop, burn, disc, bed, plant.	Necessary Necessary	Necessary Necessary until age 5-10			X				X		50 lbs. P as GRP	150 lbs urea 50 lbs P as GGRP	100	Planting 50-75 Mid-rotation 45-75
B[10]	Savanna soils: coarse-textured, highly organic sands, VP-SWP drainage[2]		X		X	2	1	3	—	Chop or double chop double bed, plant; or chop, burn, bed, plant.	Necessary Beneficial	Necessary until age 5-10 Unnecessary	X				X				50 lbs P as GRP CSP or DAP	150 lbs P as DAP or urea 50 lbs P as GGRP or CSP	90	Planting 20-40 Mid-rotation 20-60
C	Pine-palmetto flatwoods soils: primarily sands, VP-SWP drainage[2]	X			X	1	2	3	—	Chop, disc, bed, plant; or chop, burn, bed, plant.	Necessary Unnecessary	Necessary until age 5-10 Unnecessary			X				X		50 lbs P as GRP CSP or DAP	150 lbs P as DAP, urea 50 lbs P as GGRP or CSP	75	Planting 15-30
D	Pine-palmetto flatwoods soils: primarily sands, SWP-MWD drainage[2]	X				2	1	3	—	Chop, bed; plant; or chop, disc, bed, plant.	Beneficial Unnecessary	Beneficial Unnecessary until age 5-10	X				X				50 lbs P as GRP	150 lbs. urea 50 lbs urea 50 lbs P as GGRP	75	Planting 5 to + 15 Mid-rotation 45-90
E	Upland soils, fine-textured MW-W drainage[2]		X	X		1	2	3	—	Chop, plant; or chop, burn, plant.	Unnecessary Unnecessary	Unnecessary Unnecessary			X				X		50 lbs P as DAP	150 lbs urea 50 lbs P as CSP/DAP	at planting: 25 mid-rot.: 90	Planting — 5 to + 15 Mid-rotation 30-50
F[11]	Upland soils: coarse-textured MW-W drainage[2]		X		X	2	1	3	—	Chop, plant; or plant in rough.	Unnecessary	Unnecessary	X				X				50 lbs P as DAP	150 lbs urea 50 lbs P as CSP or DAP	50	Planting — 5 to + 50 Mid-rotation 10-40
G	High pineland soils: primarily deep-dry sands, SWE-E drainage[2]				X	—	—	1	or sand pine	Chop, plant; or seed natural regeneration.	Unnecessary	Unnecessary									50 lbs P as DAP	Fert. not recommended	0	Planting — 5 to + 5
H	Organic Soils: Titi or Bay Swamps, VP-P drainage[2]					1	2	—	—	Chop, plant; or seed chop, burn, plant or seed.	Necessary	Necessary			X				X		50 lbs P as DAP	150-300 lbs Urea 50 lbs P as GRP	75	Planting — 5 to + 30 Mid-rotation 20-60

[1] Based on tables 1, 2, 4, 7, 8, and 9 in *Soils Interpretations for silviculture in the Southeastern Coastal Plain*, by Richard F. Fisher, School of Forest Resources and Conservation, University of Florida, Gainesville, FL, Nov. 6, 1980.

[2] VPD — Very poorly drained
P — Poorly drained
SWP — Somewhat poorly drained
MW — Moderately well drained
W — Well drained
SWE — Somewhat excessively drained
E — Excessively drained

[3] Spodic Horizon — if virgin, usually is a subsurface horizon of active formless material with both high water retention and exchange capacity wherein organic matter and aluminum with or without iron have accumulated.

[4] Access drainage — consists of major ditch networks necessary to lower the water table over large areas.

[5] Silvicultural drainage — refers to secondary ditch system intended to lower the water table temporarily over short distances, and bedding or mounding to give new seedlings drainage within the root zone.

[6] <5ppm phosphorus — critical level in which the nutrient phosphorus has been determined deficient in the soil for growing slash pine. >5ppm phosphorus — non-critical level in which the nutrient phosphorus is sufficient in the soil for growing slash pine.

[7] Refers to the estimated response of CRIFF's Soil Groups at planting, mid-rotation or after thinning in columns 13 and 14.

[8] Estimated from over 50 trials by the Cooperative Research in Forest Fertilization and North Carolina State Forest Fertilization Cooperative with slash, loblolly and sand pine. Concluded that stands fertilized with phosphorus at time of planting need not be refertilized.

[9] Predicted gains in cubic foot per acre per year from planting to pulpwood age or longer. Mid-rotation predicted gains in cubic foot per acre per year to end of rotation period.

[10] In South Carolina, CRIFF Soil B "counterpart"; first choice would be to plant to loblolly pine. (Charles McKee, personal communication Dec. 3, 1982).

[11] Soil group F is planted to longleaf on MW drained sites in South Carolina. Second choice loblolly pine, with P levels above 1 ppm is not responsive to additional phosphorus. In most cases sites in South Carolina and perhaps Georgia will be planted to loblolly pine. The threshold of response to P is dependent on drainage; a very poorly drained site may require 7 to 10 ppm available P for loblolly, while a MW drained site does not require more than 1 to 1.5 ppm available P (Charles McKee, personal communication Dec. 3, 1982).

Determination of Nutrient Requirements

Soil test and foliar analysis are methods used to detect soils which are low in primary or secondary nutrients. Research results have proven that foliar analysis is more reliable than soil analysis; but one must remember that soils are available for testing where:

- -Sites are without vegetation.
- -Sites have trees suppressed by other species.
- -Sites have large trees and soils sampling is easier.
- -Timber is a factor.

This means the reliability of foliar analysis depends upon winter sampling; wherein, soil testing can be administered throughout the year. Table 2 shows the approximate critical levels of Nitrogen (N), P, and Potassium (K) which slash and loblolly pine would be expected to respond to fertilization.

Table 2 - Critical soil and foliar levels below which a growth response to fertilizer can be expected.

		Soil extraction method		Foliar plat test	
Element		NH_4OAC (ammonium acetate)	$HCl+H_2SO_4$ (double acid)	Slash	Loblolly
				Total analysis (by weight)	
		ppm		percent	
Nitrogen	N	-	-	0.80-1.0	1.0-1.2
Phosphorus	P	1.5-2	4-6	0.08-0.09	0.09-0.10
Potassium	K	10	10	0.25-0.30	0.25-0.30

1/ Pritchett and Gooding 1975; Wells 1969.

Procedures For Collecting Material For Foliar Testing

1. Take separate samples in areas of significantly different soil or stand conditions.

2. A minimum of 15 dominant or codominant trees randomly selected from an area should represent the composite foliage sample for testing. A composite should consist of at least 200 needles (a bunch that can just be encircled by the thumb and forefinger) free from soil contamination.

3. Collect the sample between January and March, and avoid sampling during extreme weather conditions not typical of the season.

4. Select samples from a primary lateral branch in the upper third of the crown (essentially free from light competition) on the south side of the tree.

5. Needles should be in their last, fully matured, flush of growth on the primary lateral (figure 2).

6. Store the sample on ice or place it in a dryer within 12 hours of collection. Dried samples are preferred for transporting to the laboratory. Drying is best done in a forced air oven at temperatures of 60-70 degrees C (140-160 degrees F) for 24 to 48 hours.

7. The test for nutrients in soils or foliar samples can be administered at most agricultural colleges. The cost ranges from $0-5 per sample. Analyses done at most land-grant colleges may not give values in the range required for pine response to P because the laboratories' services primarily meet the needs of agricultural crops.

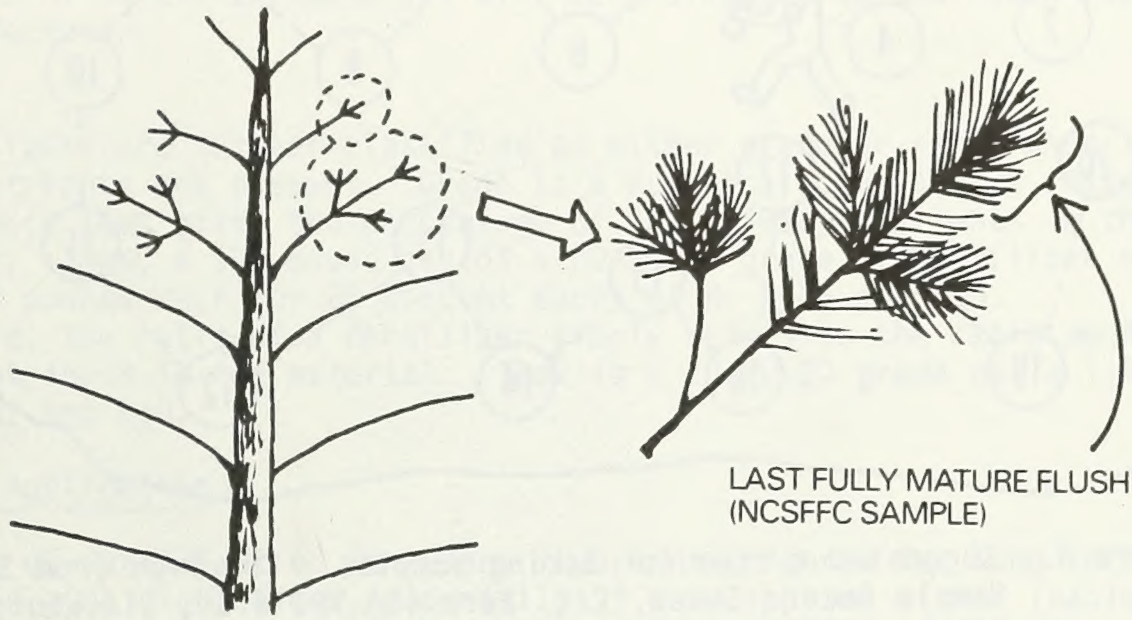

Figure 2. An example of foliage sampling position. (Derived from Figure 8, forest soil fertilization short course by H. Lee Allen, North Carolina State Forest Fertilization Cooperative; July 1983).

Procedures for Collecting Soil Samples

A reliable soil sample should be taken in a clean container within the 3-6 inch depth of the soil surface in a uniform soil area. The sample should be composed of at least 20 sub-samples, thoroughly mixed and spread on paper to air dry. After the mixed sample is dried, place 1 pint of soil in a bag and label for transporting to the lab.

If there are visible differences in soils or tree growth in a stand, a separate sample should be taken from each uniform soil area of uniform tree growth (figure 3). Do not take sub-samples from eroded spots, back furrows, small depressions, and other unusual areas. Large areas in an open field that

was manured, limed, fertilized or otherwise managed differently in the past should be sampled separately. Remember to always dry soil samples at room temperatures and NEVER dry samples in an oven, because oven drying will change the levels of extractable nutrients within the sample.

The accuracy of a soil or foliar analysis depends largely upon whether the samples are true representatives of the "subject" being sampled. For soils, most of the same principles are used in sampling a forested area as on a tract of farmland. One important difference is that forested lands usually have a well developed organic layer on the surface of the soil, and this layer should be scraped away before a sample is taken.

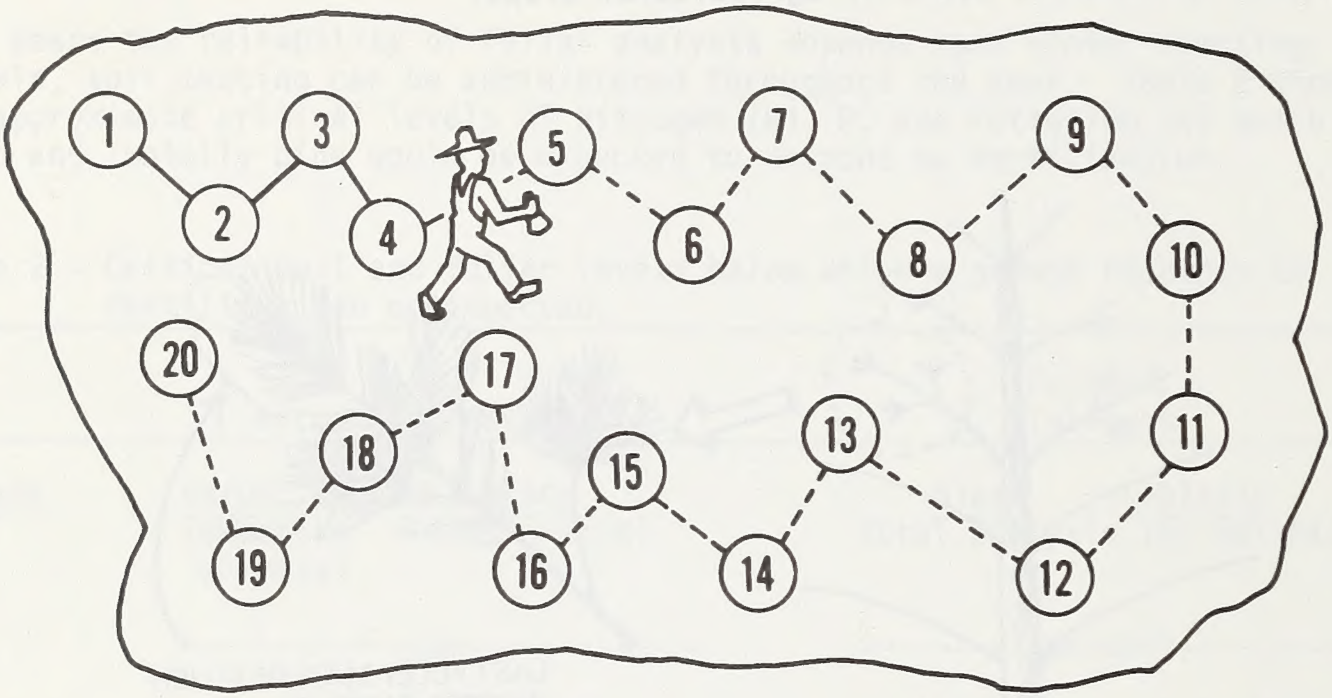

Figure 3. Suggested system for taking samples. (Derived from Soil Sample Record Sheet, Ext. Form 48A VPI & SU, Blackburg, VA, October 1972).

Fertilizer Sources

There are a number of choices of P fertilizers for forestry as in agriculture. The selection of the appropriate fertilizer for the site is based on the tree species, soil type, cost of the nutrient, method of application and environmental problems associated with it's use or misuse.

Basically, six types of fertilizer material are used in forest fertilization in the Atlantic Coastal Plains of the South. These are ground rock phosphate (GRP), concentrated superphosphate (CSP), granulated ground rock phosphate (GGRP), diammonium phosphate (DAP), ammonium nitrate (AN), and urea. Fertilizers are designated as either straight material or mixed. A straight material is one which contains only one of the primary nutrients (N, P, or K). A mixed fertilizer is one which contains either two or all three of the primary nutrients (table 3) and varying quantities of secondary and trace elements.

Table 3 - Common fertilizer carriers used in forest fertilization in the Southeast.

Fertilizer Material[1]	Approximate analysis		
	N	P	K
	%	%	%
Ground rock phosphate	0	11-18	0
Concentrated phosphate	0	20	0
Granulate groundrock phosphate	0	11-18	0
Diammonium phosphate	18	20	0
Urea	46	0	0
Ammonium nitrate	33.5	0	0

[1] Analysis of fertilizer material will vary slightly depending on source and manufacturer.

Fertilizers are further classified as either grade or ratio when the primary nutrients are present. Grade is a numerical code always stated in the same sequence that gives the percentage of the primary nutrients in the fertilizer. Thus, a 100-pound bag of a 20-20-20 grade of fertilizer would contain 20 pounds each (or 20 percent each) of N, P_2O_5 and K_2O. Furthermore, the ratio of a fertilizer simply refers to the ratio among the primary nutrients in the material. That is a 20-20-20 grade has a 1:1:1 ratio of N, P_2O_5, and K_2O.

Timing of Application

Timing of fertilization is a very important criteria for long term response in pine plantations, especially if N is applied with P (table 4). The best time to apply fertilizer (or a combination of N and P with herbicides) is at or near the time of planting. Applications should be made by June of the first year. In this way, site deficiencies are corrected before seedling growth becomes severely retarded. Usually, waiting a full year could reduce the expected gaines in volume growth by as much as 50 percent. The earlier trees can rid themselves of competition from weeds, the better the response to fertilization will be. N is a source of fertilizer that is highly leachable and can move rapidly below roots of recently planted trees, especially in sandy soils, when applied too early. Therefore, when N is applied alone it should be applied in bands, or spots near the tree but not broadcast and never placed directly into the planting hole. The succulent roots of plants could be destroyed by this strong chemical fertilizer. N fertilizer is applied alone to young trees and can generate an increase in weed population, which competes for water and the additional N forcing a short term suppression in the tree growth.

The response to phosphorus fertilization on phosphorus deficient sites is generally quite dramatic and long term in nature. A single application of phosphorus should give sustained responses lasting 15 to 20 years and response may continue into a second rotation.

Table 4 - Ten-year results from one CRIFF test on timing of fertilization of CRIFF D-Soil Groups.

Timing of Fert. Application	P 1/ Cubic/ft./acre/year	N & P 2/ growth response
2 mo. before planting	87.9	93.6
At planting	95.7	125.1
Mid-June, year 1	99.0	129.6
September, year 1	93.3	98.4
Mid-March, year 2	80.7	85.2

Control growth = 68.4

1/ 100 lbs. P/acre
2/ 100 lbs. P/acre, 100 lbs. N/acre

Economics of Fertilization

First, fertilization must be biologically and economically feasible. Second, fertilization of timber is a business that involves the outlay of cash in today's market with the expectation of generating a profitable return in tomorrow's market. If past management practices have caused a site to be depleted of sufficient nutrients for proper stand development then one can expect the next generation of trees to respond to fertilization.

According to industry, researchers and others, not fertilizing when a site is responsive to the addition of nutrients will lead to a loss of income; and fertilizing when the site is non-responsive will lead to a loss of capital. Also it is difficult to generalize the magnitude of response which might be expected from forest fertilization. However, any stand with the potential to gain 1/2 cord of wood per acre per year over that site's original growth rate would produce an economically viable return on investment. Such gains translate from 8 to 15 feet increase in site index (25 years) if fertilizer (specifically P) is applied at or near time of planting. However, as shown in figure 4, this does not prevent the possibility of getting additional response from a later application of P.

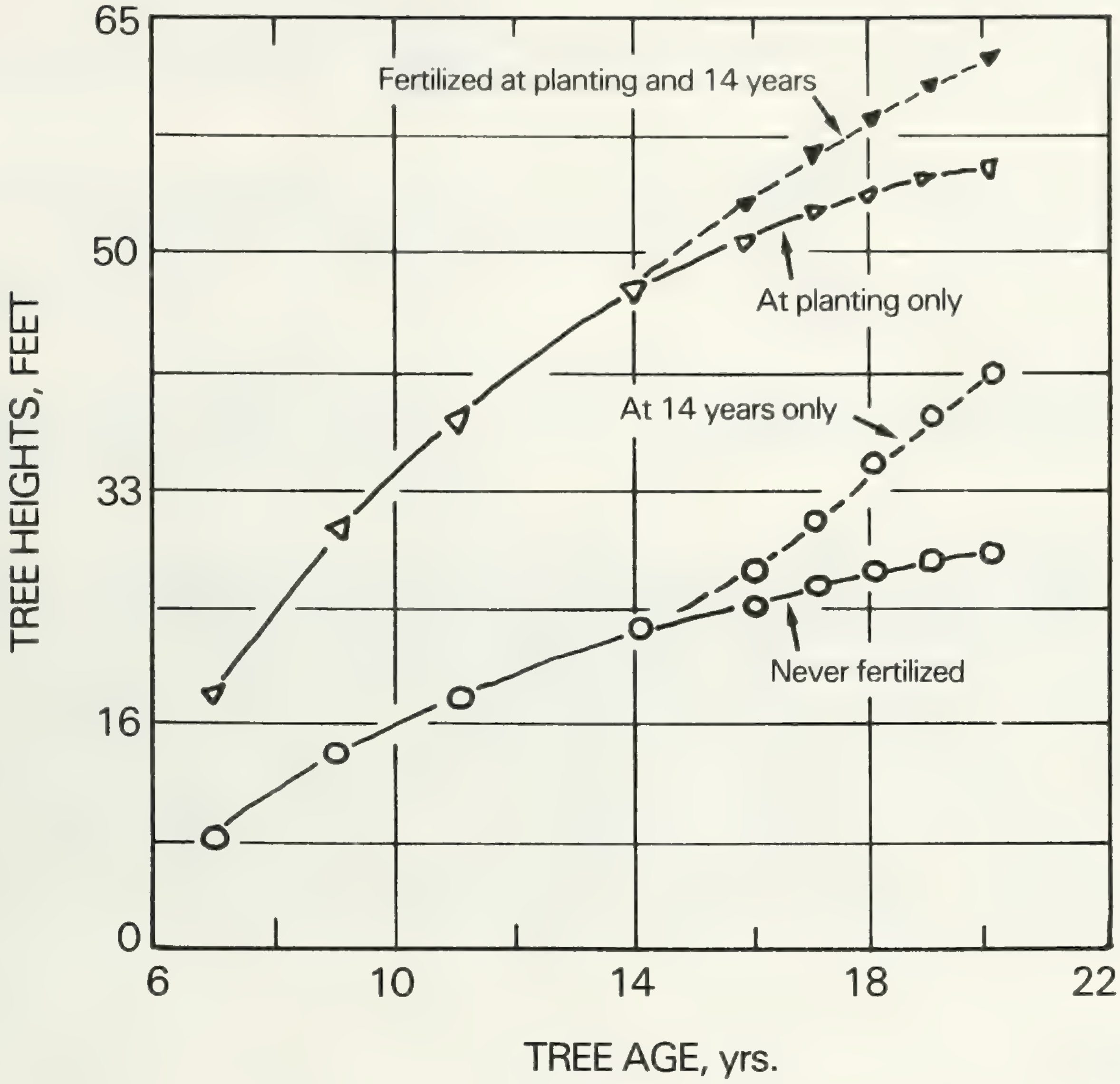

Figure 4. Mean height of slash pine fertilized at planting and/or after 14 years on a phosphorus-deficient wet soil.

Source: Pritchett. W. L. Phosphorus in forest soils. Phosphorus in Agriculture. 67:27-35. 1976.

The following site conditions depict where fertilization and soil restoration methods may be useful although volume gains may not initially pay for the full cost of the treatment.

Site Condition	Corrective Recommendations
1. Soil Compaction	May require a decade or more to recover naturally. Subsoiling and fertilization would shorten the recovery period.
2. Acute soil nutrient deficiency	Fertilization would enhance forest site productivity on suitable soil types.
3. Site under intensive management	Fertilization would maintain site productivity.
4. Restoring abused sites caused by exploitative use	Soil restoration and fertilization would improve recovery period.

Before you invest in forest fertilization you should: 1) understand the problems with each site and how to overcome them, 2) select the most appropriate nutrient source for the site in question based on soil type, species, ecological considerations, and economic considerations, 3) apply the material in a form and manner that would maximize its use, 4) evaluate the amount of additional wood produced in relation to the value of that additional wood at harvest. Remember the key to the future use of fertilizers still lies with research and modern technology. Hopefully, fertilizers in the future will not only be used to supplement nutrient losses in forest soils; but will be used as a stimulus to unlock a natural process that would trigger soil nutrients to replenish themselves indefinitely.

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